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SURFACE ROUGHNESS METER

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incidence of light gives a reflectance which is greatly
influenced by the rms slope of the surface profile and so
reflection results are entirely different with the same
rms surface roughness when the surface roughnesses have
different rms slopes. This has limited the usefulness of
gloss meters for quantitative roughness measurements,
particularly in the range of from 10 microinches down and
at best only gross qualitative indications of poor
reproducibility can be obtained.

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The present invention utilizes a particular type
and organization of two-color photometer to measure
roughness. The incident light used is normally in a very
narrow angle about normal incidence and great accuracy is
obtainable, far beyond anything given by a profilometer
even with very hard material particularly in the range
below 5 microinches. It has been determined that at
normal incidence the reflection is an exponential function
of the square of the rms roughness in which the ratio of rms
roughness to the wavelength reflected is a factor in the

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exponent. The instruments of the present invention
translate the ratio of reflectances at two different
wavelengths into a result from which the surface roughness
can be derived, preferably automatically by the operation
of the instrument. Instruments using the difference of
the reflectances are also useful but somewhat less precise.

As stated above, the instrumental solution of
the problem might appear *prima* *facie* feasible. However,
there are other factors which render a direct solution,
generally applicable to all ranges of roughness impossible,

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or so complex as to be impractical.

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- 2 -

1 | radiation be available it is not necessary that this small

2 | spread be fixed and for some purposes an instrument which

3 | permits readings at small angular spread and at a larger

4 | one has uses and is, therefore, not excluded from the

5 | present invention.

6 | When used in its normal mode with the small

7 | angular spread of radiation beam and the other limiting

8 | factors the present instrument performs something that has

9 | not been possible with optical instruments of the gloss

10 | meter type, namely the measurement of rms roughness with

11 | high precision regardless of variation in the rms slope of

12 | the surface irregularities and regardless of whether the

13 | roughness is random or oriented. This new result is of

14 | great practical importance.

15 | While the radiations used in the instrument can

16 | be any optical radiation, (i.e. ultraviolet, visible or

17 | infrared), the preferred results are obtained with somewhat

18 | longer wavelengths than visible light. For example two wave-

19 | length bands in the near infrared are desirable. With suf-

20 | ficiently fine surface roughness an instrument operating on

21 | the two-color principle described above can, in principle,

22 | be used in visible light only or with one color of the two-

23 | color photometer in the visible and the other in the infra-

24 | red. With these shorter wavelengths color differences some-

25 | times present problems. Surfaces tend to reflect much more

26 | like gray bodies in the infrared than in the visible. How-

27 | ever, where the nature of the material, the roughness of

28 | which is to be measured, permits, radiations in the visible

29 | may be used. As most of the practical instruments, according

30 | to the present invention, are particularly designed for

In Fig. 1 a radiation source (1), such as an incandescent lamp which radiates in the visible and the near infrared, produces a beam of light which is condensed by the lens (2) and passes through a pinhole (3) in a plate. In a practical instrument this pinhole may be approximately 0.031" in diameter. The beam from the pinhole is focused by a lens (4) and is split by a beam splitter (5). One beam is focused onto the roughness sample or sample holder (6). The light passing through the beam splitter (5) is rejected. From the roughness sample reflected light passes through the beam splitter (5), is collimated by conventional optics (7) and transmitted to a prism (8) which can be pivoted about the point (9) to choose different portions of the spectrum generated at the plane of a mask (11). The dispersed light is then imaged by the lens (10) onto the plane of the mask (11) provided with two slits (12) and (13). The particular spectral bands transmitted by these slits pass through a field lens (14) onto a lead sulfide detector (15). The beams are chopped by a conventional chopper (16) turned by a motor, (not shown). The chopper incorporates conventional reference wave generating means shown diagrammatically as a pickup coil (17) which cooperates with a magnetic insert in the chopper, (not shown). Any other type of reference generator may be used, such as an opening with a light and a photocell. The output from the radiation detector (15) is then introduced into a phase sensitive amplifier (18) which also receives the reference square wave from the pickup (17). The difference in the signals from the two beams through the slits (12) and (13)

(13) should preferably be from 10 to 30 times longer than

the rms roughness. For measurements in the range of 0.1 /

microinch to about 10 microinches, suitable wavelengths

are approximately 0.8μ and about 2.5μ. For other ranges

of roughness different wavelengths can be used, and this

can be effected by turning the prism (8). Ordinarily even

for a versatile laboratory instrument a few pairs of

wavelengths will suffice and so the movement of the prism

may be to a limited number of predetermined positions,

for example as determined by conventional stops.

The instrument measures rms roughness in the

range referred to above with accuracy and does not damage

the surface, something which is impossible in this range

with a profilometer. When coarser roughnesses are to be

measured, the present instrument is still useful though

of course it may be necessary to utilize somewhat longer

wave infrared in order to maintain the desired ratio

between wavelength and surface roughness. Even in ranges

and with hard materials where a profilometer can be used,

the present instrument gives a reading which is more

constant where the roughness is oriented. When scratches

are parallel to each other, the profilometer reading will

change depending on the direction in which the stylus is

moved across the surface, whereas the optical measurement

depends on the spectral effect of the rms roughness value

and is substantially insensitive to sample orientation.

It, therefore, gives improved results even in a range

where the old-fashioned profilometer could be used.

As noted above, the logarithmic transmittance

function generated by the wedge (20) results in a wedge

1.5μ. Rays pass through the two filters and then through

objective (26), continuing on through the field stop (30)

and field lens (31) to illuminate the two halves (27) and

(28) of a split detector. Each half receives radiation

from a single filter only. In front of the filters is a

rotatable cap (25) provided with a suitable angular scale

which is not shown. This member has a solid portion (32)

and a semicircular opening (29). The cap is shown in

Fig. 4 at the position where the beams through the two

filters are equally attenuated, (i.e. halved), by the cap.

For convenience this setting corresponds to 45° on the

angular scale, while at 90° filter (23) is 3/4 open and

filter (24) is 1/4 open. At 135° filter (23) is completely

opened and filter (24) is completely closed.

The differential output passes through an

amplifier (18). The amplifier output registers on a meter

(19). The operation of the instrument can best be

considered by reciting the sequence of a measurement. First

a standard surface is placed at (6). This may be a

completely smooth surface with zero rms roughness or it

may be a sample of known rms roughness. The cap (25) is

then turned until the meter (19) shows zero output. The

angular setting of the cap (25) will be designated as θ_1 .

The sample of which the roughness is to be measured is then

inserted and again the cap (25) is turned until once more

there is a null reading on the meter. The resulting

angular setting of the cap will be designated as θ_2 . The

ratio of the exposed areas of the two filters is defined by

the following fraction:

$$\frac{135° - \theta}{45° + \theta}$$

transformed into the two spectral bands and both come from
the same beam. This more complicated instrument permits
the measurement of surfaces which are not flat and in fact
extends the present invention to curved surfaces such as
spherical surfaces of reasonable curvature. It now becomes
possible to measure the rms roughness of spheres which is
of importance in the ball bearing industry.

While there are limitations to the precision of
measurement of different types of samples on the simplified
instrument, for a large number of purposes where the
samples are reasonably flat the results are entirely
satisfactory and so it is possible in such cases to
utilize the extremely cheap and compact instrument of
Fig. 3. It is an advantage of the present invention that
it is very flexible and instruments of differing degrees
of complexity and versatility are available so that the
best compromise in terms of instrument versatility versus
cost can be chosen in each case.

The two Figs. (1) and (3) show two different
techniques of producing radiation bands of suitable
spectral width. It should be understood that this does
not mean that the single beam instrument of Fig. 1 must
always employ a monochromator. It is possible to take the
single beam and split it with conventional beam splitters
and utilize filters. Such variations are, of course,
included within the scope of the present invention as
recited in the claims.

- 12 -

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wavelength bands of the reflected beam, the wavelength of
the shorter band being at least ten times as long as the
maximum rms roughness to be measured, a radiation detector,
means for imaging the two selected narrow bands of the
reflected beam thereon, means for attenuating at least
one of the narrow bands, means for chopping the radiation
located intermediate the light source and the detector,
means for generating a reference signal said means being
actuated in synchronism with the chopping means, a phase
sensitive AC amplifier, means for connecting the output
of the radiation detector to the input of said amplifier,
and means for indicating polarity and magnitude of the
amplifier output whereby said means indicate a function of
the relative amounts of radiation in the two bands striking
the detector.

4. An optical roughness measuring instrument
for measuring rms roughness over a predetermined range
comprising, in combination and in optical alignment, a
source of optical radiations, means for producing a narrow
beam therefrom of suitably low divergence, a roughness
sample holder, means for directing said narrow beam onto
the surface of said holder at substantially normal
incidence to produce a reflected beam, means for selecting
two narrow wavelength bands from the reflected beam, the
wavelength of the shorter band being at least approximately
thirty times as long as the maximum rms roughness to be

is at least about thirty times the maximum rms roughness to be measured.

9. An optical measuring instrument for measuring rms roughness over a predetermined range comprising in combination and in optical alignment a source of optical radiations, means for producing a beam thereof of suitably low divergence, a roughness sample holder, means for directing said beam onto the surface of said holder at substantially normal incidence to produce a reflected beam, two filters passing different narrow wavelength bands in said beam, the wavelength of the shorter band being at least 10 times as long as the maximum rms roughness to be measured, means for varying the relative cross-sections of the beam striking the filters, radiation detectors in the filtered beams, means for producing a differential output from said detectors and amplifying and indicating means connected thereto.

10. An optical measuring instrument for measuring rms roughness over a predetermined range comprising in combination and in optical alignment a source of optical radiations, means for producing a beam thereof of suitably low divergence, a roughness sample holder, means for directing said beam onto the surface of said holder at substantially normal incidence to produce a reflected beam, two filters passing different narrow wavelength bands in said beam, the wavelength of the shorter band being at least 30 times as long as the maximum rms

FIG. 1

FIG.2

PHASE
SENSITIVE
AMPLIFIER

FIG. 3

FIG.4